Microcogeneration with stirling engine and solar power: Energetic balance in Mediterranean climate

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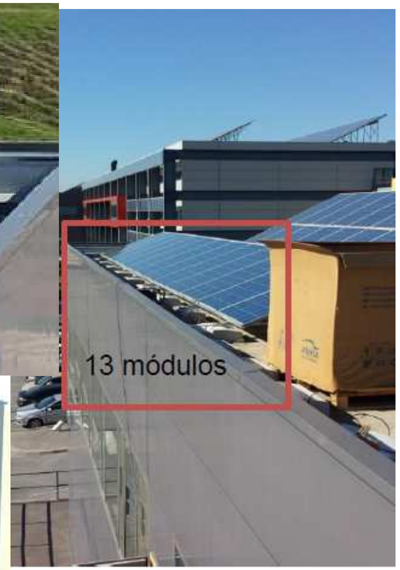


2. Material and Methods

- Laboratory of Cogeneration in University of Malaga

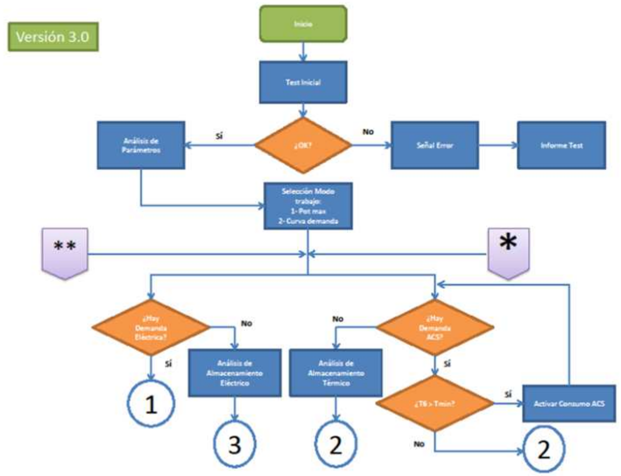
Table 1. Technical characteristics of the system

Stirling micro-CHP	
Model	Whispergen EU1
Engine	4 Cylinders double acting Stirling cycle
Electrical output	Up to 1 kW
Thermal output	Up to 7 kW
Fuel consumption	1.55 m³/h
Solar thermal system	
Collector model	Chromagen
Collector area	3.54 m²
Recommended flow	45 l/h·m²
Maximum pressure	10 bar
Storage tank capacity	300 l
Electronic DC/AC control	
Inverter model	Ingeteam Sun Storage 1play 3TL
Storage system connection	
Voltage rank	48-300 V
Maximum charge/discharge	50 A
Photovoltaic connection	
Voltage rank	300-450 V
Maximum intensity	20 A
Consumption connection	
Maximum permanent power	3000 W
Maximum intensity	13 A
Performance	
Maximum efficiency	95.5 %
Euroefficiency	95 %
Accumulation system	
Battery Model	LG Chem Resu 10 Li-Io
Nominal Voltage	51.8 V
Voltage Range	42.0-58.8 V
Usable Energy	8.8 kWh
Capacity	189 Ah
Photovoltaic system	
Nominal peak power	3000 Wp
Nominal power of the modules	245 Wp
Module efficiency	15.04 %
Intensity of maximum power	8.33 A
Voltage of maximum power	29.37 V

2. Material and Methods

- **Laboratory of Cogeneration in University of Malaga**

  - A control system based in a **PLC Mitsubishi,** with an interface, commands the whole system and manages the production and the activation of the loads according to a provided flowchart



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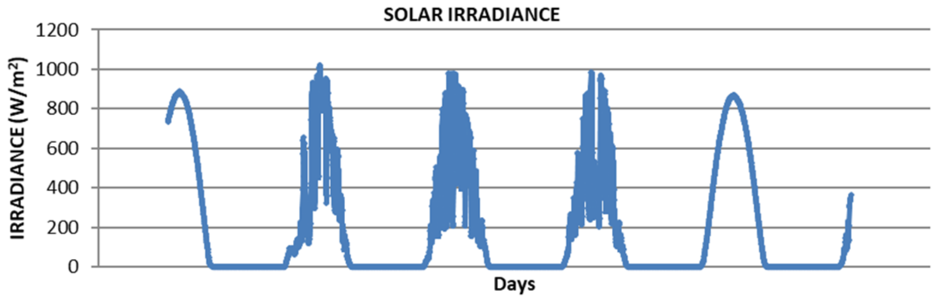
3. Theory/Calculation

- Energy production



- Energy demand

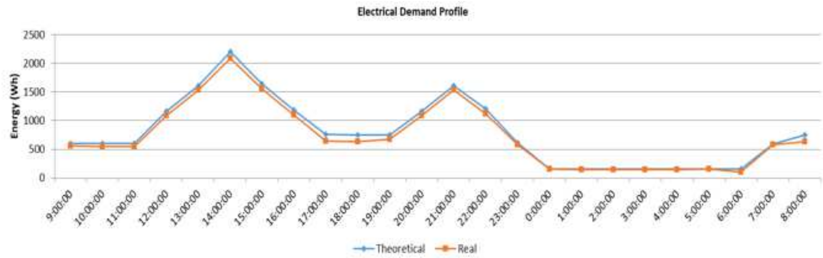


Figure 4. Example of electrical demand

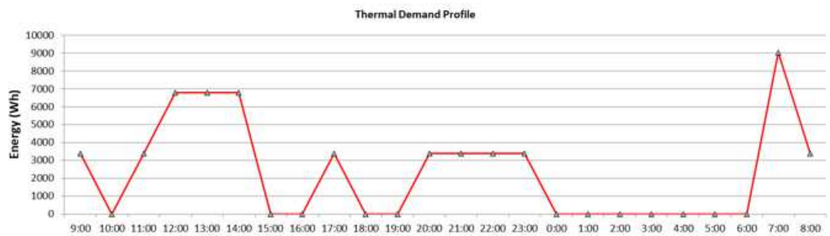


Figure 5. Example of thermal demand

3. Theory/Calculation

For the system analysis, these concepts are defined:

PV efficiency (η_{pv}) $$\eta_{PV} = \frac{PV\ energy\ (\varepsilon_{PV})}{Solar\ Radiation(\varepsilon_{rad})}$$

Thermal efficiency (η_{th}) $$\eta_{th} = \frac{Thermal\ Energy\ (\varepsilon_{th})}{Solar\ Radiation(\varepsilon_{rad})}$$

System efficiency (η_{s}) $$\eta_{s} = \frac{Produced\ Energy\ (\varepsilon_{p})}{Solar\ Radiation(\varepsilon_{rad}) + Gas\ energy(\varepsilon_{gas})}$$

System net efficiency (η_{sn}) $$\eta_{sn} = \frac{Used\ Energy\ (\varepsilon_{pn})}{Solar\ Radiation(\varepsilon_{rad}) + Gas\ energy(\varepsilon_{gas})}$$

Reduction in CO_2 emissions (CO_{2r}) :

$$CO_{2r} = Network\ \text{emissions}\ (CO_{2NS})\ \text{- System emissions}\ (CO_{2S})$$

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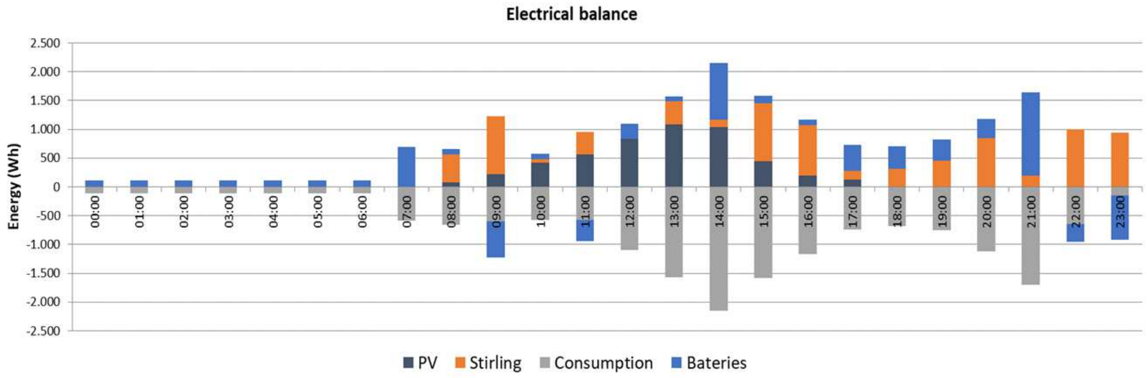
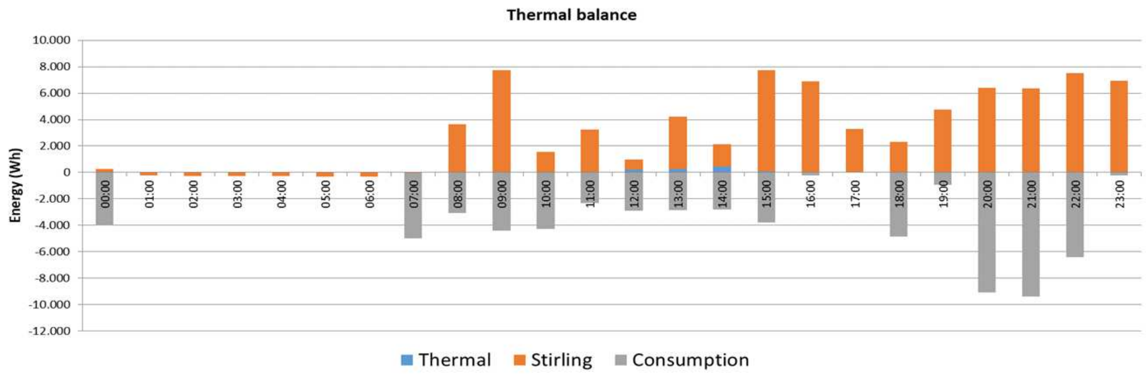
4. Results

- Analysis in a **critical** day

Table 1. Energy balance of a half-overcast day

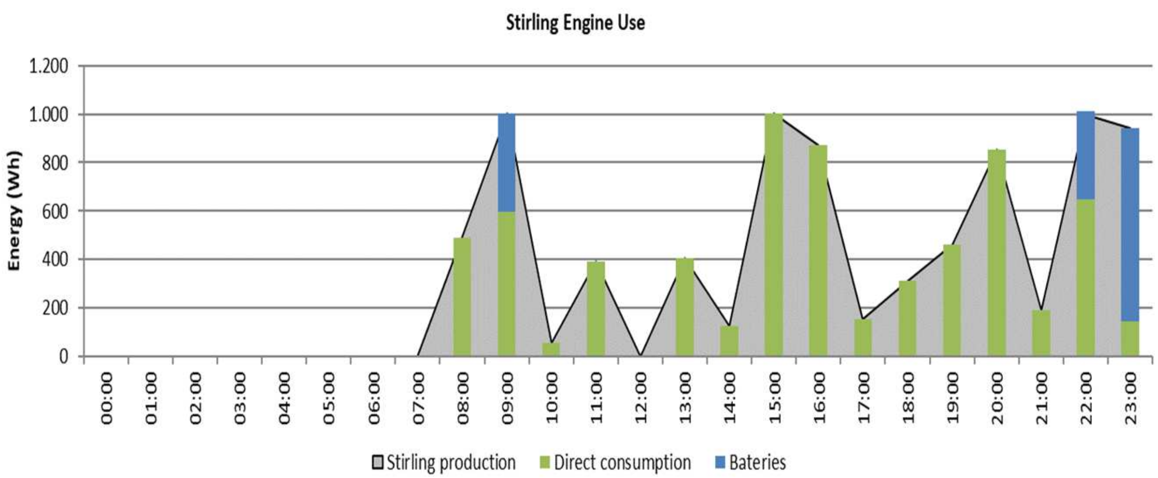
Energy Balance (Wh)	
Solar radiation	46236
PV energy	4997
Solar Thermal energy	1017
Solar energy produced	6014
Gas energy consumed	94186
Stirling energy produced	81000
Produced energy	87014
Used energy	90352





4. Results

Stirling engine works only when **solar energy is not enough**:
Thermal or electrical



5. Discussion

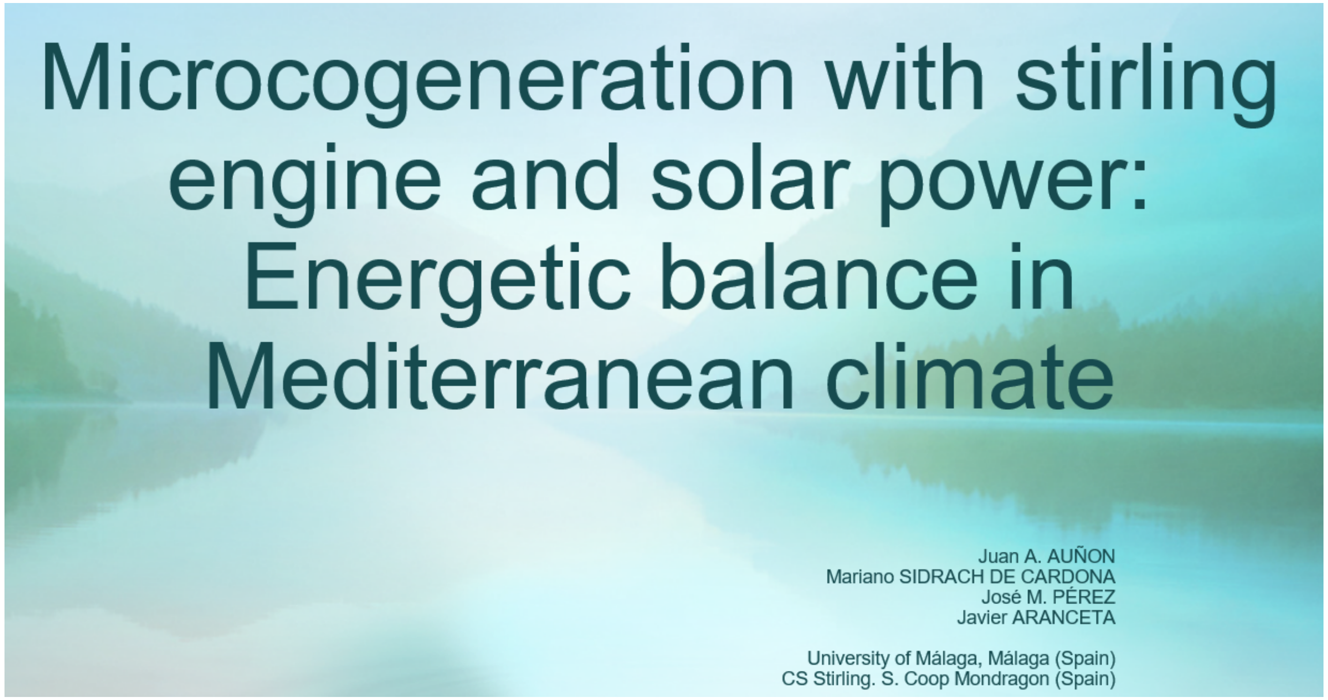
Example of a daily balance

Energy Production (Wh)		**Energy Balance**	
Solar radiation	46236	CO_2 emissions (kg)	19.21
PV Energy	4977	Equivalent network	
Solar Thermal Energy	1017	CO_2 emissions (kg)	25.93
Total Solar Energy produced	6014	Reduction CO_2	25.90%
Gas energy consumption	94186	Stirling efficiency	0.86
Stirling energy produced	81000	PV efficiency	0.11
Total energy produced	87014	Thermal efficiency	0.02
Used energy	90352	System efficiency	0.62
		Net system efficiency	0.64

COGENERATION IMPROVES ENERGY EFFICIENCY

6. Conclusions

- The results show that this system has **capacity to cover energy demand**, electrical and thermal, for a small building with different demand profiles in both types of energy.
- The system could cover 100% of energy regardless of weather conditions.
- The CO_2 emissions reduction with respect to Spanish network emissions is from 25% in overcast days to 100% in sunny days.



Thank you very much for your attention.

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